

A STRUCTURE AND MANUFACTURING METHOD OF CHIP SCALE PACKAGE

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to the manufacture of integrated circuit (IC) chips, and in particular to the packaging of chips at the chip level. At the same time, packaging of chips relates to chip bonding, including the current wire bonding, to Chip Scale Packaging (CSP) test fixture concerns, and the attendant reliability concerns.

(2) Description of the Related Art

Packaging of IC chips determines to a large extent the performance of the system of which the chips are the smallest building blocks. As one chip must communicate with one or more other neighboring chips in order to perform a system function, the method by which the chips are packaged and interconnected makes a difference in their speed of communication. For example, current mini-BGA (Ball-Grid-Array) packages using wire bonding as interconnection are not as effective in high frequency circuit applications.

Also, chip scale packaging (CSP) is important in determining the type of fixtures that must be used for testing. It is disclosed later in the embodiments of the present invention a CSP package and a method of manufacturing the same which substantially improves the performance of the IC chips as well as the testing cost of the chips.

As is known in the art, integrated circuits are formed on a silicon wafer which is then diced or cut to form individual die, also called chips. The circuits which are interconnected in each chip terminate at terminals on the chip. The appropriate chips are then interconnected with each other by bonding those terminals onto a card having its own interconnections. Depending upon the complexity and function of the final machine that is to be built, this first level package may in turn be interconnected with other first level cards by connecting the cards onto a second level package, usually called a board.

The chip level interconnection forming the first level package is usually performed using wirebonding (WB), tape automated bonding (TAB), or flip-chip solder connection, sometimes referred to as controlled collapse chip connection (C4). A detailed description of each of these interconnection schemes will not be given here so as

to not obscure the key aspects of the present invention, and also, as they are not necessary to the understanding of the teachings of the present invention.

A conventional first level mini-BGA package, (10), is shown in prior art Fig. 1. The die, or chip (20) is wire-bonded (40) to substrate (30), which in turn is connected to second level package (70) through solder connections (60). The mini-BGA package is always encapsulated in a molding material (50). It will be known to those skilled in the art that it would be desirable to eliminate wires (40). Such a method is disclosed later in the embodiments of the present invention. Some other prior methods of making connections to chips are disclosed in US Patents 5,994,766 by Shenoy et al., 6,118,183 by Umehara, et al., 6,137,164 by Yew et al., 5,734,201 by Djennas et al, and 5,914,533 by Frech et al., where they use redistribution layers. Lau, on the other hand, shows a low-cost surface mount compatible land-grid array (LGA) chip scale package (CSP) for packaging solder-bumped flip chips. Higgins also discloses a CSP mounted to a substrate using direct chip attach (DCA) method.

The present invention, as disclosed later, differs from prior art in that a CSP is formed by integrating a redistributed chip on a substrate. The I/O solder balls are

first mounted through the substrate vias, which in turn are connected to the chip I/O pads. The substrate is attached to the chip by an adhesive.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide a Chip Scale Package (CSP) having improved chip attachment especially suited for high frequency circuit application.

It is another object of the present invention to provide a more reliable CSP than current CSP.

It is still another object of the present invention to provide a CSP which leverages current test infrastructure to be more cost effective.

It is yet another object of the present invention to provide a method of forming CSP with improved interconnections.

It is an overall object of the present invention to provide a method of attaching chips directly to an adhesive-

substrate (adsubstrate) as well as attaching an adhesive-wafer (adwafer) directly to a substrate in order to form CSPs with minimized interconnection lengths and hence, enhanced circuit speed.

The objects of the invention are accomplished by providing a silicon chip having I/O pads; an under-ball metallurgy (UBM) layer on the surface of said I/O pads; a substrate with an adhesive (adsubstrate), and having openings corresponding to the locations of said I/O pads; and ball mountings formed over said adsubstrate and reaching said UBM layer over said I/O pads on said chip.

The objects are further accomplished by providing a wafer having a plurality of chip sites with I/O pads; forming an under-ball metal (UBM) layer over said I/O pads; forming an adhesive layer over said UBM layer on said wafer to form an adwafer; forming openings in said adhesive layer on said adwafer to reach said I/O pads underlying said UBM layer; die sawing said adwafer to form said chip scale package (CSP); providing a substrate having openings corresponding to said I/O pads; attaching said CSP with said adhesive to said substrate; and forming ball mountings on said openings on said substrate to attach to said I/O pads on said CSP.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view of a portion of a conventional mini-BGA, according to prior art.

Fig. 2a is a cross-sectional view of a portion of a semiconductor chip showing the forming of an area array I/O pads, according to the present invention.

Fig. 2aa is a transverse cross-sectional view of a portion of the semiconductor chip of Fig. 2a showing the UBM layer on the I/O pads, according to the present invention.

Fig. 2b is a cross-sectional view of a portion of a semiconductor chip showing the redistribution of I/O pads in a redistribution layer to form an area array of I/O pads, according to the present invention.

Fig. 2c is a cross-sectional view of a portion of a composite adsubstrate structure comprising an adhesive layer formed over a substrate, according to the present invention.

Fig. 2d is a cross-sectional view of a portion of the adsubstrate of Fig. 2c showing the forming of through via holes, according to the present invention.

Fig. 2e is a top view of a portion the adsubstrate of Fig. 2d showing the area array of via openings, according to the present invention.

Fig. 2f is a cross-sectional view of a portion of a chip package formed by adhering a multiplicity of chips to the adsubstrate of Fig. 2d, according to the present invention.

Fig. 2g is a cross-sectional view of a portion of the chip package of Fig. 2f showing the encapsulation of the same, according to the present invention.

Fig. 2h is a cross-sectional view of a portion of the encapsulate chip package of Fig. 2g showing the forming of ball mounts, according to the present invention.

Fig. 2i is a cross-sectional view of a portion of the chip scale package (CSP) of the present invention after sawing off of the same from the chip package of Fig. 2h, according to the present invention.

Fig. 2j is a top view of a portion of the patterned stencil where solid areas (161) prevent the adhesive material printing to the substrate while open areas (163) allow the adhesive material to print on the substrate, thus forming the adsubstrate of Fig. 2e, according to the present invention.

Fig. 3a is a cross-sectional view of a portion of a wafer showing the forming of an adhesive layer, according to the present invention.

Fig. 3b is a cross-sectional view of a portion of the wafer of Fig. 3a showing the opening of the area array I/O pads, according to the present invention.

Fig. 3c is a cross-sectional view of a portion of a substrate showing the area array openings, according to the present invention.

Fig. 3d is a cross-sectional view of a portion of the substrate of Fig. 3c and of the wafer of Fig. 3b, showing the attachment to each other, according to the present invention.

Fig. 3e is a cross-sectional view of a portion of the wafer of Fig. 3d, showing the encapsulation in a molding material, according to the present invention.

Fig. 3f is a cross-sectional view of a portion of the encapsulated wafer package showing the forming of ball mounts, according to the present invention.

Fig. 4 is a cross-sectional view of a Chip Scale Package (CSP) of the present invention, showing that the invention can perform on a chip designed without the area array pads, and with no distribution layer, according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, that is, to Figs. 2a-2i, and Figs. 3a-3g, there are shown steps of forming a Chip Scale Package (CSP) with improved interconnections.

More specifically, Figs. 2a and 2b show two single chips die sawed from a wafer, preferably silicon. Chip (100) in Fig. 2a is either already designed to have an area array (AA) of input-output (I/O) pads (110) in passivation

layer (120), or, optionally, the same chip in Fig. 2b has normal design I/O pads which have subsequently been redistributed in a re-routing (RR) layer (130) to form redistributed AA pads (140) as shown in Fig. 2b. An under-ball metallurgy layer, comprising nickel and copper, that is, (UBM) layer (115), is also formed over pads (110) or (140), better seen in cross-sectional view in Fig. 2aa. It is important that the pads on chips are generally in an area array configuration for easier connection to the next level of packaging, as is known in the art.

It is also known in the art that chip sites are first formed on a semiconductor substrate to form a wafer, where the substrate is provided with pads (110/115) or (140/115) that are connected to underlying multi-level metal layers through intervening insulating dielectric layers, and ultimately to integrated circuit devices that have already been conventionally formed within and on the substrate. These conventional steps are well known in the art and as they are not significant to the invention, they are not described in detail here in order not to unnecessarily obscure the present invention. However, it is described below in the embodiments of the present invention a new method of forming a chip scale package (CSP) where the I/O ball connections are directly mounted on the chip through vias formed in a next level of substrate.

Thus, as a key aspect of the present invention, substrate (150), preferably a bismaleimide triazine (BT), having a thickness between about 150 to 300 micrometers (μm) is mounted with adhesive layer (160), having a thickness between about 10 to 100 μm . Layer (160) can be a polyimide thermocompression adhesive SPA made by Nippon Steel Chemical. The adhesive and the substrate together form an "adsubstrate" composite structure, reference numeral (165), as shown in Fig. 2c. The composite adsubstrate is then either mechanically drilled, or, preferably laser drilled with an area array of via openings (170) that correspond to AA I/O pads (110) or (140) on the chip, as shown in Fig. 2d. A top view of the adsubstrate with AA openings is also shown in Fig. 2e.

It is important that the vias in the adsubstrate align with the I/O pads on the chip, for at the next key step, the chips are attached to the adsubstrate to form a chip package, reference numeral (105), as shown in Fig. 2f such that the vias reach the I/O pads. The attachment is achieved by subjecting the chip package to an assembly pressure between about 1.5 to 2.5 Megapascals (Mpa) and at the same time, to a temperature between about 250 to 350°C. Next, the chip package assembly is encapsulated with a molding material, preferably, epoxy based resin to a thickness between about 100 to 500 μm . It will be obvious

to those skilled in the art that other molding materials for electronics can also be used.

It is now a main feature of the present invention to perform ball mounting over the via openings of the adsubstrate, where the chip package is inverted such that the mounting material, preferably, solder is "balled" up as shown in Fig. 2h. It is further preferred that the solder comprises tin-lead, or, tin-silver alloy. During continued process, solder flows to reach the I/O pads at the bottom of the vias, as shown in Fig. 2h. As a final step, the encapsulated chip package is die sawed to form the Chip Scale Package (CSP) of the present invention, as shown in Figure 2i. Fig. 2j shows an alternate method of silk screening an adhesive material on to substrate (167) with holes corresponding to the AA I/O pads on the chip. That is, Fig. 2j is a top view of a portion of the patterned stencil where solid areas (161) prevent the adhesive material printing to the substrate while open areas (163) allow the adhesive material to print on the substrate, thus forming the adsubstrate of Fig. 2e.

In a second embodiment shown in Figs. 3a-3f, the main feature is where the adhesive material is applied to wafer

(300) to form an "adwafer" first. The adwafer, with a plurality of chip sites, has aluminum pads (320) with an optional re-routing (RR) dielectric layer (330) and passivation layer (310) separating the pads from adhesive layer (350), as shown in Fig. 3a. It will be noted that the I/O pads are connected to RR metal layer (340) which redistributes the ordinary pad configuration to an Area Array (AA) pad configuration where the redistributed AA pads are terminated with a barrier metal (345), which acts as an under-ball metallurgy (UBM) as seen in both Figs. 3a and 3b. It is preferred that the UBM comprises copper and nickel, and has a thickness between about 1 to 50 μm . The adhesive film can be formed on the wafer by either spin coating, screen printing or lamination under pressure, where the latter is preferred.

Openings (360) in adhesive layer (350) reaching barrier metal (345) are next formed by either laser drilling, photolithographic methods, or by silk screening the AA configuration onto the adhesive layer in the first place. It is preferred that laser drilling is employed in this instance. The adwafer so prepared is then diced into Chip Scale Packages, or, CSPs.

As a key aspect of the second embodiment, a substrate (370), similar to the BGA substrate (150) used in the first

embodiment, is next prepared with drilled via openings (380) corresponding to the AA pad array on the CSPs to be attached as shown in Fig. 3c. It is preferred that substrate (370) comprises BT and has a thickness between about 150 to 300 μm . Then the CSP of Fig. 3b is die attached to substrate (370), as shown in Fig. 3d. This is accomplished at a pressure between about 1.5 to 2.5 Mpascals and temperature between about 250 to 350 $^{\circ}\text{C}$. The resulting package is next encapsulated (300) using a molding process as shown in Fig. 3e. This is followed by another key feature of the second embodiment, namely, a reflow ball mounting (400) process over openings (360) that connect to the AA I/O pads of the chip sites within the wafer, as shown in Fig. 3f. This is accomplished by forming solder comprising tin-lead or tin-silver alloy.

Though these numerous details of the disclosed method are set forth here, such as process parameters, to provide an understanding of the present invention, it will be obvious, however, to those skilled in the art that these specific details need not be employed to practice the present invention. At the same time, it will be evident that the same methods may be employed in other similar process steps that are too many to cite, such as, for example forming a CSP product without a re-routing metal

layer which is replaced by an UBM layer such as shown in Fig. 4.

It will thus be apparent to those skilled in the art that the disclosed invention can improve the performance of the various levels of packaging in computers through the use of solder connections in place of wire bonding. At the same time, the disclosed Chip Scale Packaging (CSP) can improve the testing cost by keeping the same body size of chip using the same size substrate. The conventional CSP's on the other hand, have varying body sizes, and therefore, requiring different test fixtures. Even more varying sizes are expected with shrinking product sizes, especially with memory products, and hence, large over-head expenditures for the well-known back-end testing on the production line. This is not the case with the uniformly formed CSPs of the present invention. The presently disclosed CSP's can also provide improved thermal reliability by encapsulating the chips with molding materials that will reduce the coefficient of thermal expansion (CTE) mismatch between the silicon chip and the next level of packaging. Hence, molding materials other than those described here may also be used without departing from the letter and spirit of the invention.

That is, while the invention has been particularly shown and described with reference to the preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the spirit and scope of the invention.

What is claimed is: